Lobster Eye X-Ray Imaging Underwater Scatterometer

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LONG-TERM GOALS

The Lobster Eye X-Ray Imaging Underwater Scatterometer (LEXIUS) being developed by Physical Optics Corporation (POC) is an underwater X-ray imager/scatterometer system for high-quality imaging of mines and other objects buried in seabed sediment. The system, mounted on a small underwater vehicle, which could be a remotely operated vehicle (ROV) or autonomous underwater vehicle (AUV), operates by detecting backscattering X-rays; it does not endanger Navy personnel during operation or maintenance.

OBJECTIVES

The overall goal of this project is to develop an advanced, robust, reliable LEXIUS system for underwater detection of buried mines by means of high-quality backscatter imaging, and suitable for mounting on small underwater vehicles.

APPROACH

The LEXIUS approach is based on X-ray Compton scattering. When an object is irradiated by X-ray with energies from 40 to 150 keV (or wavelength λ = 0.31 to 0.08 Å), Compton scattering occurs, and some of the X-rays are backscattered. Materials have intensity values of Compton backscattering that depend on their atomic numbers (Z numbers). The relative probability of these interactions—the Compton scattering differential cross section—is a function of the Z number of the material, and of the scattering angle, described by the Klein-Nishina formula. LEXIUS operates by focusing and acquiring backscattering photons simultaneously from the entire 2D large-area scene irradiated by a wide-open cone. For this purpose POC developed hard X-ray lobster eye (LE) focusing optics. A lobster (or shrimp, crayfish, or other crustacean) views the world through a large number of long, narrow cells shaped like square tunnels, combined in a spherical array with a common center of curvature and >180° field-of-view. For hard X-ray applications, the cells must be very long, with lengths greater than 100 times their widths, but the optical principle remains the same as that in the eye of the crustacean. LEXIUS integrates LE X-ray focusing optics, X-ray generators, an X-ray camera, and a real-time image acquisition and processing algorithm implemented in embedded processor in a compact underwater system for detection of buried mines.

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14. ABSTRACT
The Lobster Eye X-Ray Imaging Underwater Scatterometer (LEXIUS) being developed by Physical Optics Corporation (POC) is an underwater X-ray imager/scatterometer system for high-quality imaging of mines and other objects buried in seabed sediment. The system, mounted on a small underwater vehicle, which could be a remotely operated vehicle (ROV) or autonomous underwater vehicle (AUV), operates by detecting backscattering X-rays; it does not endanger Navy personnel during operation or maintenance.

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Key Personnel:

Principal Investigator/Program Manager, Michael Gertsenshteyn, Director of Photonic Technologies, **and engineering staff,** brings to the project his expertise in X-ray detectors and in X-ray focusing technology. Specifically, he is responsible for the fabrication of the LE optics and LEXIUS assembly, and for testing. As an expert in design and prototyping of electro-optical imagery systems for acquisition and processing of images in the X-ray, visible, and near-infrared spectral ranges he is also performing full end-to-end computer simulation of the LEXIUS system.

Image Acquisition and Processing Support, Ilya Agurok, Director, Optical Technologies, brings to the project expertise in ray-tracing and design of optical elements; he is responsible for the LEXIUS X-ray lens optical elements, and for testing their properties. Specifically, he is performing ray-tracing and optical analysis and optimization of lobster eye lenses for high-resolution image backscatter imaging.

Russell Kurtz, Director, Holographic Systems, and staff will bring to the project expertise in image acquisition and processing. He is implementing the design, assembly, and testing of an X-ray image acquisition system based on a scintillator and intensified CCD camera, analog-to-digital converter, and digital signal processor, and is performing image processing calculations.

Gajendra Savant, Chief Operating Officer, brings to the project expertise in fabrication of the optical elements and LEXIUS product commercialization. Specifically, he is responsible for communication with government agencies, partners, and potential investors. Dr. Savant brings to this project expertise in productization and commercialization of prototypes such as LEXIUS.

Richard Koziol, Mechanical Engineer, brings to the project expertise in design and packaging of X-ray systems. He is expert in Pro/E design and in using Pro/E to simulate mechanical strength, support materials choice, and design the thermal management of the LEXIUS system, integrated inside a waterproof housing for underwater X-ray imaging capabilities.

WORK COMPLETED

The following tasks were completed or are ongoing after the first three months of the project.

Initial development of an optimized LEXIUS system design. We have developed and optimized the LEXIUS prototype design by increasing the effective collecting area of the LE X-ray lens, and adapted the thermal management of the X-ray generator for operation in a waterproof housing to meet Navy requirements. We have selected the optimal combination of X-ray photon wavelength (energy) and total flux coming out of the X-ray generator, field-of-view (FOV), number of elements, and geometry of the LE lens, scintillating screen, and cooled CCD camera. Based on the overall system architecture, the specifications of the individual elements in the LEXIUS are established. This includes the specifications of the X-ray generator, water-based cooling system, and X-ray image readout electronics.

The initial design and packaging of the LEXIUS system have been performed in Pro/E. The mechanical strength, choice of materials, and thermal management of the underwater system are being considered.

The exact design of the LE hard X-ray lens has been developed by X-ray ray-tracing of the LE structure under simulated conditions. POC finalized the design and fabrication of the LEXIUS waterproof stainless steel housing for the X-ray generator, backscatter X-ray detector; electronic processing; and a water-based cooling system. The housing will have mechanical and electrical interfaces for compatibility with small underwater vehicles.

IMPACT/APPLICATIONS

Projected military markets for LEXIUS include detection and classification of buried underwater metal and plastic mines and mine-like objects; ROV/AUV-based MCM, replacing dolphin MCM programs; land MCM; and screening at military security checkpoints. Civilian markets include medicine, nondestructive evaluation (NDE) of products, and hard X-ray astrophysics for NASA applications. Homeland security applications include security screening at airports and borders, and marine terminal cargo/container scanning.

TRANSITIONS

The contract was just initiated a few months ago. As we make progress towards finalizing the design, fabricating the components, and integrating the system, we will be in a better position to demonstrate the results and capability of the LEXIUS system. Our marketing department has already taken steps to contact potential users in the military as well as civilian customers.

RELATED PROJECTS

Roadside Explosive Device X-ray Detecting System
(Navy Contract No. N00014-04-M-0380)
Contact: Clifford Anderson *Completion:* 11/30/04 *Phone:* (703) 696-4485

Handheld Lobster Eye X-ray Inspection Device (HSARPA Contract No. NBCH050054)
Contact: Gerald Kirwin *Completion*: 04/24/07 *Phone*: (202) 254-5773

PUBLICATIONS

M. Gertsenshteyn, T. Jannson, and G. Savant, "Staring/Focusing Lobster-Eye Hard X-Ray Imaging for Non-Astronomical Objects," invited paper at SPIE conference Hard X-Ray and Gamma-Ray Detector Physics VII, *SPIE Proc.*, vol. 5922, (in press) 2005.

PATENTS

Michael Gertsenshteyn, Thomas Forrester, Tomasz Jannson, Kang Lee, and Gajendra Savant, Lobster Eye X-ray Imaging System and Method of Fabrication Thereof, assignee: Physical Optics Corporation, Docket No. 2005.02, Serial No. 11/191,095, filed on July 27, 2005.